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Abundance and biomass of *Pardosa agricola* (Thorell) (Araneae, Lycosidae) on a shingle bank of the River Lune (Lancashire)

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Summary

The lycosid *Pardosa agricola* was studied in spring and summer 1974 on a sparsely vegetated shingle site on a river island.

The spiders overwinter as subadults and have reached maturity by May.

Cocoon production of *P. agricola* starts in the middle of May. A female spider produces about 40 offspring per first cocoon. The first young spiders occur in June, at which time the adults begin to move from bare shingle to more vegetated sites. Spiders of the second cocoon appear from the beginning of August. The density on the shingle was 1.4 adults/m² at the end of May, 32 young spiders per m² in July and 19 young spiders from the first and second cocoon in August. The biomass of lycosids on the shingle was always between 16 and 20 mg/m² dry weight.

Introduction

This study is part of a project concerned with the animal community associated with *Rumex obtusifolius* L., which is one of the pioneer plants on "Thrush Gill" island in the River Lune near Hornby, Lancashire (Grid ref. SD 579706). This shingle island measures 240 m x 75 m and is flooded periodically.

The most conspicuous arthropods on the ground are lycosid spiders and small carabids. Three species of lycosids are abundant: *Pardosa agricola* (Thor.), *P. amentata* (Cl.) and lower numbers of *Arctosa cinerea* (Fabr.). *P. agricola* could be found everywhere on the island and was by far the most abundant lycosid. It occurs mainly in the north of Britain and is confined to shingle banks by fast rivers away from the coast (Locket, Millidge and Merrett, 1974). *P. amentata* occurred by the water on the part of the island near to the wooded north bank of the river. It has been studied by Edgar (1970), Kessler (1971), Schmidt (1957) and Vlijm *et al.* (1963). Another lycosid spider, *Arctosa cinerea*, was first found at the end of May. It lives under stones in silken tubes, and is restricted to the shingle parts of the island. Locket and Millidge (1951) state that "it appears to stay in its tube even when the river rises and covers the stones during the winter months". So this not uncommon species could well have been overlooked before.

Some other spider species were found: *Oedothorax fuscus* (Bl.), *Oe. apicatus* (Bl.), *Troxochrus scabriculus* (Westr.), *Diplocephalus latifrons* (O.P.-C.) and *Bathyphantes gracilis* (Bl.). *Oedothorax apicatus* is distributed over the whole island. This minute linyphiid seems to be the most abundant spider species on the island.

A number of subadults of *Pachygnatha* sp. Sundevall were caught in the autumn of 1973 but these seem to be visitors, because adults or young could not be found. This study attempts to determine the abundance and biomass of *Pardosa agricola* on very sparsely vegetated shingle.

Methods

Data were collected in spring and summer 1974. The abundance of *P. agricola* was determined by mark-recapture sampling for adults and direct counting for juveniles on two 100 m² grids. Both grids were situated on the south side of the shingle bank facing out into the main stream which is approximately 20 m wide at this point (Fig. 1). The grids were 3 m apart, the more easterly grid being called Grid 1. Mark-recapture sampling was carried out from 25-31 May 1974. Female spiders were collected by means of a hand aspirator, anaesthetized in the laboratory with CO_2 and marked with cellulose paint on the sternum (see Edgar, 1971b, Hackman, 1957). Different colours were used for different days. The spiders were released on the following day and recapture took place one day later. There were two periods of recapture on Grid 1, and one on Grid 2.

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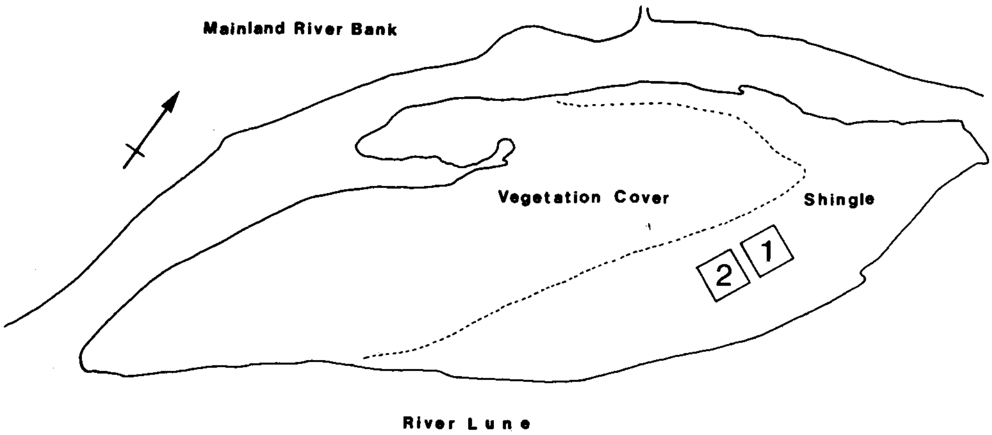

Fig. 1: Diagram of Thrush Gill Island with Grids 1 and 2. Scale 1:2,000.

Grid 2 was subdivided into an easterly and westerly part of 50 m^2 each. The spiders on each side of the grid were marked with different colours.

The hand sampling method has the disadvantage that the study site is disturbed by the investigator when collecting the spiders. On the other hand, extensive preliminary studies showed that abundance estimates by a mark-recapture method with live pitfall trapping were not possible. When two or more spiders were present in a trap they damaged or even killed each other although the traps were emptied daily.

The abundance of young spiders was determined by placing a 25 x 25 cm metal frame in random positions on the two grids. The spiders in the enclosed area were caught with an aspirator. Every stone had to be removed and examined carefully. A total of 12 samples was taken in both grids. This method is only applicable to slow animals which are easy to catch.

Spider weight was determined on a Mettler five place analytical balance. For the determination of dry weight, spiders were dried for at least 48 hours at 60°C.

Results

Life cycle data of P. agricola

Most of the individuals of *P. agricola* overwinter as subadults but with few exceptions reach maturity at the beginning of May. At the end of May most of the males of *P. agricola* had died and more than two-thirds of the females caught with an aspirator were carrying cocoons (Table 1). On the cooler north side of the small island very few *P. agricola* females with cocoons could be seen at this time of year.

In the middle of June we found young spiderlings, females with and without cocoons and with young spiders on their backs; males were not seen.

In the middle of July mainly young spiders occurred on the grids. Only a few females were found there but they were more abundant on the more vegetated regions. Some of them were carrying their second cocoon.

In August young spiderlings from the second cocoon were seen on the shingle for the first time.

	Date	Number of females with cocoon	Number of females without cocoon	Percentage of females with cocoon
Grid 1				
	25 May	49	11	81.7
	27 May	31	14	68.9
	29 May	16	8	66.7
	mean	32	11	74.4
Grid 2				
	29 May	48	22	68.6
	31 May	41	15	73.2
	mean	44.5	18.5	70.6

Table 1. Numbers and percentages of female *P. agricola* with and without cocoons caught with an aspirator on south side of island

Density estimates

a) in May

The results of the mark-recapture sampling which was carried out at the end of May are given in Table 2. Two periods of recapture on Grid 1 made it possible to calculate the density with the simple Lincoln Index and with Bailey's triple-catch index (Southwood, 1971, p. 75-88). A large proportion of spiders seemed to leave the grid during the investigation period. Thus with the same amount of effort we caught 57 spiders on 25 May, 45 on 27 May and only 24 on 29 May. However, according to the Lincoln indices and the loss and dilution rates from Bailey's formulae (Table 2), the density of the spider population should have increased during these days whereas our direct observations showed that it declined.

Day	n_i	x	y	z
1	57			
2	45	27		
3	24	2	2	5

n_i = number of female spiders caught
x = number of female spiders marked on day 1 and recaught
y = number of female spiders marked on day 2 and recaught
z = number of female spiders marked on both days and recaught

Sampling occasion 1	Sampling occasion 2	a	n	r	P	S.D.
Day 1	Day 2	57	45	27	95	12
Day 2	Day 3	45	24	7	141	39
Day 1 & 2	Day 3	75	24	9	187	44
Day 1	Day 2 & 3	57	69	29	133	19

a = original number of marked spiders
n = total number of second sample
r = total number of recaught spiders
P = estimated population size

Bailey's index for small samples: $P = \frac{45 \times 46 \times 7}{28 \times 8} = 64.6$

S.D. = 33.0

Dilution rate: log 2.06 = 0.314
Loss rate: log 0.79 = −0.102

* The formula: $P = \frac{a \times n}{r}$ was used, when r was bigger than 20.

The variance was estimated by:

$$\text{var } P = \frac{a^2 \times n\,(n - r)}{r^3}$$

When r was less or equal 20, a correction for small samples proposed by Bailey (1951, 1952) was used:

$$P = \frac{a\,(n + 1)}{r + 1}$$

The variance was then estimated by: $\text{var } P = \frac{a^2 \times n\,(n - r)}{r^3}$

Table 2. Estimates of densities of female *P. agricola* on Grid 1 in May obtained by the Lincoln Index* and Bailey's Index

We assume that the actual density is somewhere around 90 female spiders per 100 m^2 on Grid 1 (Table 2). Males were present in negligible numbers.

The density on Grid 2 appears to be higher (Table 3). It may have been slightly overestimated because with the simple Lincoln Index we have not considered emigration and immigration. But even if we assume that ten marked spiders have left the grid (a = 67 at the time of marking would change to a = 57 at the recapture date) and that ten unmarked spiders had entered the grid (of n = 56 only n = 46 would belong to those spiders which had been present on Grid 2 at the time of marking), the estimated density would be 134 which is still higher than the Bailey estimate on Grid 1.

Site	a	n	r	P	S.D.
East	43	31	11 (white)	115	25
West	24	25	6 (green) 2 (white)	89	27
Whole grid	67	56	19	191	34

Table 3. Estimation of densities of female *P. agricola* on Grid 2 in May by the Lincoln Index. Symbols as in Table 2

The mean density is probably about 150-200 female spiders on Grid 2. The higher density of adult female spiders on the more westerly grid, together with the finding that later in the year adult spiders were only found in the more vegetated parts of the island which are west and north of the two grids, suggest that at this time of year the spiders are beginning to leave the bare shingle site and move to the more vegetated parts. Edgar (1971b) also observed seasonal movements in adult *Pardosa lugubris* (Walck.). The spiders with cocoons spent the springtime in clearings, moved back into the woodland in late July, leaving the unshaded area to the young

	Numbers weighed	Mean fresh wt. (mg) ± S.D.	Mean dry wt. (mg) ± S.D.
Spiders plus cocoon and spider with distended opisthosoma	15	40.9 ± 7.7	12.1 ± 2.3
Spiders with cocoons (weighed without cocoons)	14	23.0 ± 3.5	6.2 ± 0.9
Cocoons	14	17.1 ± 4.1	5.7 ± 1.2
Cocoon shells	13		0.98 ± 0.3

Table 4. Mean fresh and dry weights of *P. agricola* at the end of May

spiderlings, and returned to the clearing in late August with their second cocoons. They overwintered in oak woodland. Hackman (1957) in a study on *Trochosa ruricola* Deg. states on p. 32 that "juvenes and adults prefer different zones of the shore at different phases of their life (moulting juvenes, cocooning females)".

b) in July and August

On 18 July many young spiders and only a few adults were present on the two grids. The mean number of the former was 2.00 ± 0.37 per sample ($1/16\ m^2$) or 32 per m^2.

On 6 August spiderlings from the second cocoon were present but in fairly low numbers. The mean density was now 1.17 ± 0.32 per sample or 19 per m^2 which is significantly lower than the density on 18 July ($p < 0.01$).

Biomass estimates

a) Adult females

On 29 May the fresh and dry weight of 15 adult female spiders was determined. Fourteen of them were carrying cocoons, and one had not yet produced an egg-sac. This does not represent the natural population, because just over two-thirds of the females had cocoons, as shown in Table 1. As no better data are available we make the assumption that the weight of spiders plus cocoons is approximately the same as the weight of spiders as yet without cocoons. The spiders without cocoons had distended opisthosomata and would have produced their egg-sacs in a fairly short time. Weights are given in Table 4, and Table 5 gives the biomass estimates for the total population at the end of May.

b) Young spiders

The mean fresh and dry weights of young spiderlings in July and August are given in Table 6.

The fresh weights were determined directly. Dry weight was determined directly in May for adult spiders and in July for juvenile spiders. The dry weight of spiders in August was calculated by means of a regression between fresh weights and dry weights of adult and young spiders from May and July:

$$y = -0.14 + 0.29x \ (r = 0.994)$$

Biomass estimates for new recruits to the population are given in Table 7, which also summarizes the population data for the period of study. It is interesting to note that the biomass of lycosid spiders on the shingle remains nearly constant over the time of the investigation.

	Number present per 100 m²		Standing crop dry weight g per 100 m²	
	Grid 1	Grid 2	Grid 1	Grid 2
Spiders, still without cocoons	23	56	0.28	0.68
Spiders with cocoons	67	134	0.41	0.82
Cocoons	67	134	0.38	0.77
Total population	90	190	1.07	2.27

Table 5. Approximate abundance and biomass (standing crop) of *Pardosa agricola* on Grids 1 and 2 at the end of May

Date	n	Mean fresh weight in mg ± S.D.	Mean dry weight in mg ± S.D.
18 July 74	21	2.26 ± 0.62	0.62 ± 0.21
6 August 74	13	4.06 ± 2.41	1.04

Table 6. Mean fresh and dry weight of young spiderlings

Reproduction

At the end of May, 13 cocoons were weighed and the eggs or spiderlings in them counted. The fresh weight of a cocoon was 15.6 ± 3.11 mg. The number of offspring was 41.3 ± 7.3, mainly spiderlings. There were some unfertile eggs and dead spiderlings so that the mean number of living offspring was 39.9 ± 6.7.

In addition we determined fresh weight and dry weight of another 14 cocoons collected on the same day (Table 4). From these data we can assume a fresh weight : dry weight relationship of 3:1. The same ratio should also apply to the cocoons we have used for the determination of number of offspring. Thus the dry weight of one offspring is:

$$\frac{\text{dry wt. of cocoon} - \text{dry wt. of cocoon shell}}{\text{number of eggs}} = \frac{5.2 - 0.98}{41.3}$$

$$= 0.102 \text{ mg.}$$

Estimates of number of eggs per cocoon and egg weights for other *Pardosa* species are given by Edgar (1971a) and Kessler (1971, 1973).

The number of eggs per first cocoon found by Kessler (1973) for eight *Pardosa* species in the field ranges from 27 – 86. Edgar (1971a) found for the first cocoon of *P. lugubris* a mean of 36.7 eggs.

Kessler (1971) has determined the dry weight of eggs from laboratory cultures and found values ranging from 0.08 – 0.113 mg for four *Pardosa* species, the highest value being for *P. lugubris.* Edgar (1971a) gives a fairly high individual egg weight of about 0.5 mg fresh weight for *P. lugubris,* which should be about 0.17 mg dry weight, using the regression for fresh weight – dry weight relationship given in his 1971c paper on p. 142.

Date	Numbers per m²	Biomass (dry weight) mg per m²
End of May (adults)	1.4	16.7
July (young)	32	19.8
August (young)	19	19.8

Table 7. Approximate abundance and biomass of *Pardosa agricola* on shingle

Discussion

The mark-recapture method is open to criticism when used for density estimates of spiders. One important assumption is not fulfilled, that of equal catchability. In lycosids there occur great differences in activity in relation to sex and life stage. Vlijm and Richter (1966) and Miyashita (1968) have demonstrated that the activity pattern during the breeding season changes considerably within a few days. These changes affect particularly abundance estimates and comparisons based on trapping methods, but it is probable that they also affect hand-sampling methods, because active spiders might be more likely to leave the investigation site and/or less active spiders might have a better chance of being overlooked. In the breeding season some males are likely to die during the investigation period. Our study was complicated by the fact that the lycosids moved from one place to another at certain times in their development. However, the structure of the ground and the fairly low density of the spiders allowed no alternative to mark-recapture methods.

We estimated a mean density of about 1.4 adult females per m^2 at the end of May. For comparison, Hackman (1957) found in June about three adult females of *Trochosa ruricola* per m shore line which was 3-4 m broad at normal water level. Hagstrum (1970) gives an estimate of 0.19 males and the same number of females of *Tarentula kochi* per m^2 pine litter in April. Edgar (1971b) found in the first half of July 2.2, 5.4, and 5.8 adult females of *P. lugubris* per m^2 in a clearing in an oak woodland.

The biomass of lycosid spiders on the shingle remained fairly constant at just under 20 mg/m^2 dry weight. The biomass of other spider species which consisted mainly of the minute *Oedothorax apicatus,* is probably lower than that of the lycosids.

Edgar (1971c) calculated for *P. lugubris* at the edge of oak woodland a mean biomass of 37.6 mg/m^2

dry weight. Cherrett (1964), who investigated the spider fauna of different sites on the Moor House National Nature Reserve, an area of high Pennine Moor, found densities of mainly linyphiid spiders between about 40-370/m^2; this corresponds to 3-47 mg/m^2 dry weight. Hagstrum (1970) observed in April a mean fresh weight of about 125 mg per adult female and about 60 mg per adult male of *Tarentula kochi.* Under the assumption of a fresh weight:dry weight relationship of 3:1 this would correspond to a biomass of 11.7 mg/m^2 dry weight. It is remarkable that bare shingle can support spider biomass of the same order of magnitude as these vegetated sites.

On the shingle site little potential food seems to be available for spiders. We assumed at the beginning of our study that lycosids are important predators on *Gastrophysa viridula* Degeer, a beetle which feeds on *Rumex obtusifolius* L. However, in 1974 *G. viridula* was very rare on the island. In the laboratory spiders could be fed on *G. viridula* larvae and in some cases on the pupae, but not on the adult beetles. Other arthropods like Diptera were much more readily taken. We assume that the investigated spider population depended mainly on airborne insects which landed at the island. They probably had another important food source in those insects which emerge from the water near the island.

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References

BAILEY, N. T. J. 1951: On estimating the size of mobile populations from recapture data. *Biometrika* **38**: 293-306.

BAILEY, N. T. J. 1952: Improvements in the interpretation of recapture data. *J.Anim.Ecol.* **21**: 120-127.

CHERRETT, J. M. 1964: The distribution of spiders on the Moor House Nature Reserve, Westmorland. *J.Anim. Ecol.* **33**: 27-48.

EDGAR, W. D. 1969: Prey and feeding behaviour of adult females of the wolf spider *Pardosa amentata* (Clerck). *Neth.J.Zool.* **20**: 487-491.

EDGAR, W. D. 1971a: Seasonal weight changes, age structure, natality and mortality in the wolf spider *Pardosa lugubris* (Walckenaer), in central Scotland. *Oikos* **22**: 84-92.

EDGAR, W. D. 1971b: The life-cycle, abundance and seasonal movement of the wolf spider, *Lycosa (Pardosa) lugubris,* in central Scotland, *J.Anim.Ecol.* **40**: 303-322.

EDGAR, W. D. 1971c: Aspects of the ecological energetics of the wolf spider *Pardosa (Lycosa) lugubris* (Walckenaer). *Oecologia* **7**: 136-154.

HACKMAN, W. 1957: Studies on the ecology of the wolf spider *Trochosa ruricola* Deg. *Commentat.biol.* **16**(6): 1-34.

HAGSTRUM, D. W. 1970: Ecological energetics of the spider *Tarentula kochi* (Araneae, Lycosidae). *Ann.ent. Soc.Am.* **63**: 1297-1304.

KESSLER, A. 1971: Relation between egg production and food consumption in species of the genus *Pardosa* (Lycosidae, Araneae) under experimental conditions of food abundance and food shortage, *Oecologia* **8**: 93-109.

KESSLER, A. 1973: A comparative study of the production of eggs in eight *Pardosa* species in the field (Araneida, Lycosidae), *Tijdschr.Ent.* **116**: 23-41.

LOCKET, G. H. and MILLIDGE, A. F. 1951: *British Spiders* **1**: 1-310. Ray Society, London.

LOCKET, G. H., MILLIDGE, A. F. and MERRETT, P. 1974: *British Spiders* **3**: 1-315. Ray Society, London.

MIYASHITA, K. 1968: Quantitative feeding biology of *Lycosa T-insignata* Boes. et Str. (Araneae, Lycosidae). *Bull.natn.Inst.agric.Sci.,Tokyo* Ser. C, **22**: 329-344.

SCHMIDT, G. 1957: Mitteilungen über sexualbiologische Beobachtungen an *Pardosa amentata* (Clerck). *Zool.Anz.* **158**: 16-23.

SOUTHWOOD, T. R. E. 1971: *Ecological methods with particular reference to the study of insect populations.* 1-391. Chapman and Hall, London.

VLIJM, L., KESSLER, A. and RICHTER, C. J. J. 1963: The life history of *Pardosa amentata* (Clerck) (Araneae, Lycosidae). *Ent.Ber., Amst.* **23**: 75-80.

VLIJM, L. and RICHTER, C. J. J. 1966: Activity fluctuations of *Pardosa lugubris* (Walckenaer), (Araneae, Lycosidae), during the breeding season. *Ent.Ber., Amst.* **26**: 222-230.